Precision Farming

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Introduction

Do you have more than one year's worth of yield maps for your fields? Have you wondered about what use you might make of them? Consider making a management unit map from your collection of yield maps for each of your fields. Two or more years of good yield monitor and GPS data are required. Presented here is a methodology for generating a management unit map that might be useful to you for making decisions. The process that I have outlined here has been adopted from a methodology developed by Larscheid et al. (1997) and Larscheid and Blackmore (1996).

The data, for the years 1995 (corn), 1996 (soybeans) and 1997 (winter wheat), used in this example is taken from a portion of one of the Ontario site specific cropping management fields. It is about 40 acres in size and consists of imperfectly to poorly drained fine sands and very fine sandy loam soils on level to gently sloping topography. More maps detailing the physical and chemical characteristics will be presented later. It is presently cropped to no-till corn, soybeans and winter wheat underseeded to red clover. Solid poultry manure is applied after winter wheat. 1995 was a dry year, 1996 was drier still and 1997 was considered to be a good year for moisture.

The idea behind the management unit map is that it should present a much better picture of the spatial variability that is consistent over time since it is derived from several years of data. If this is so, it will provide confidence that some kind of physical or chemical factor(s) has an influence on yield potential in areas where yields are consistently low.

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Software and Hardware Requirements

Software requirements:
A spreadsheet such as EXCEL and a mapping program that will allow you to overlay maps and perform arithmetic operations on them (addition and subtraction). I used both EXCEL and SURFER to complete this exercise. You must be able to convert a gridded map to a data file that can be imported into a spreadsheet.

Hardware and Space:
At least a 486 and plenty of memory. About 25 megabytes to create the data files and maps were required for this exercise. This will of, course, depend on the size of your fields and the number of years of maps.

I have also included a fair amount of detailed instructions within the steps required to make the management unit map. I hope that it won't put you off. At least have a look at the maps and the statement in bold included in each step before you leave IT. The bold type statement tells you what the map output outcome is for each step.

I would like to know if this process makes sense to you and if it will have any use. I will happily provide detailed information to you if you would like to attempt this.

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Instructions on How to SURFER

Step #1:

OUTPUT: YIELD MAPS Generate the yield maps. It is important that each map be created in the same way. What this means is: each map should have the same grid spacing and the same number of grid points. Set identical search parameters for each map. For this example I set the grid spacing at 6 by 6 meters and the search radius to 12 meters and used kriging to generate the map. All my maps are of the same size. My yield maps are presented in Figures 1, 2 and 3. Note here that the legend is different from what you are used to seeing. In this example I calculated the field average and then added and subtracted to it 3.0, 2.0, 1.0, 0.5 and .15 times the standard deviation of the field average. This procedure standardizes the yield classes and allows for a visual comparison among the years. The yellow areas represent the field average, the blue colour represents that part of the field with below average yields and the red colour is the portion of the field with above average yields. Visual inspection of the maps indicates that below average yields seem to occur in roughly the same parts of the field each year.

Figure 1 - 1995 Corn Yields Example

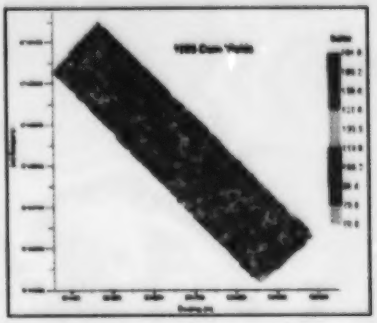

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Figure 2 - 1996 Soyabean Yields Example

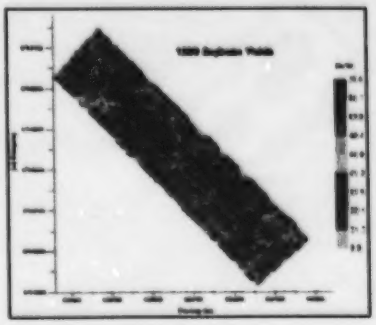

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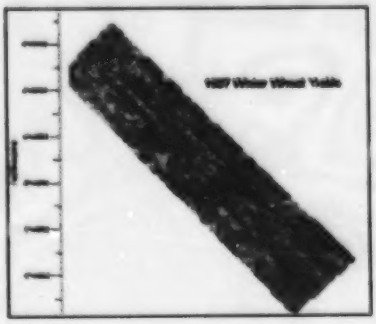
Figure 3 - 1997 Winter Wheat Yields Example



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Step 2:

OUTPUT: NORMALIZED YIELD MAPS: To begin the process of making the management unit map the yield maps need to be normalized. To do this you need to go to your yield data file and calculate the field average. Divide each yield value by the average and multiply by 100 and then recreate your maps using the normalized yield rather than the yield. Each map must be gridded in the same way (see Step 1). My 3 normalized yield maps are presented in Figures 4, 5, and 6.The legend is now expressed in terms of percent.Areas coloured shades of red represent that part of the field where the yields are greater than 100%, in other words,above average. Blue areas have below average yields.These maps look very similar to the maps in Step 1.

Figure 4 - 1995 Normalized Corn Yields

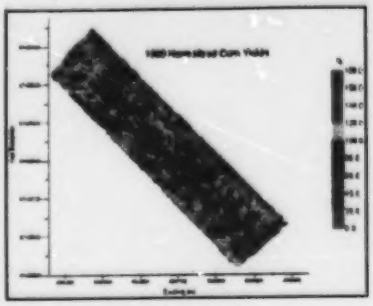

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Figure 5 - 1996 Normalized Soyabean Yields

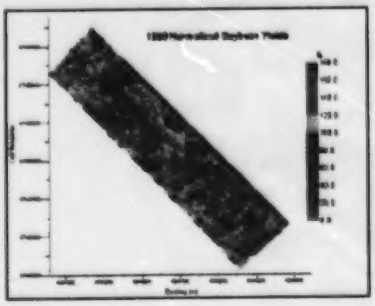

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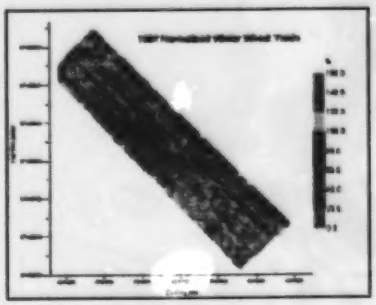
Figure 6 - 1997 Normalized Winter Wheat Yields



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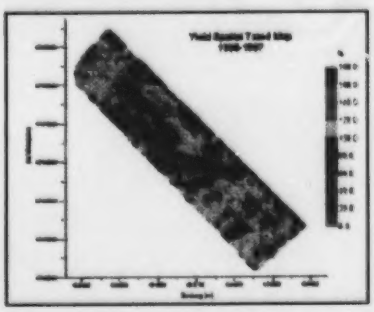
Step 3:

OUTPUT: YIELD SPATIAL TREND MAP At this point the 3 normalized yield maps are averaged. This can be done using GRIDMATH in SURFER (to complete this step successfully the normalized yield maps must have the same number of grid points).

Figure 7 - Yield Spatial Trend Map 1995-1997



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I averaged the 1995 and 1996 maps and then I averaged the new map with the 1997 map by using a weighted average (ie. average map*.66 + 1997 map * .33). Figure 7 is the yield spatial trend map which shows over the three years with three different crops where yields tend to be below or above average.

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Step 4:

OUTPUT: YIELD TEMPORAL STABILITY MAP. Things get a little complicated here. This part has to be done with SURFER. Unfortunately I haven't got very much experience with the mapping programs that are being used out there and thus I don't know how easy this would be to do using another mapping program. Each of the normalized yield maps has to be converted back to a data file. Return to SURFER, click on GRID, click on UTILITY, click on CONVERT, select the appropriate grid file, click OK, name the out file, change the save as file type to ASCII XYZ (*.dat). Each new file will have the exact same easting and northing coordinates and the exact same number of coordinates. The only thing that will differ is the value of the normalized yields. Copy the coordinates from one of the files into a spread sheet and then the normalized yield values from each yield data file. Once this is completed you must calculate the average and standard deviation for each row of data using the average and standard deviation functions. Next calculate the coefficient of variation (CV) by dividing the standard deviation by the average and multiply by 100. The coefficient of variation indicates how variable the yield data is over time. For example, the CV of 125.8, 133.6 and 113.7 is 8.1% as compared to the CV of 112.8, 7.3 and 75.5 which is 82.0%. In other words the smaller the CV the more stable the yields are over time. The yield temporal stability map is generated by gridding using the nearest neighbour function with the coefficient of variation. See Figure 8. This map shows the magnitude of the temporal changes over the 3 years. The legend of the map is expressed in %. Thirty percent is the cutoff point. Anything less than 30% indicates those areas where temporal changes are low, in other words, the yields do not vary much over time.

Figure 8 - Yield Temporal Stability Map 1995-1997

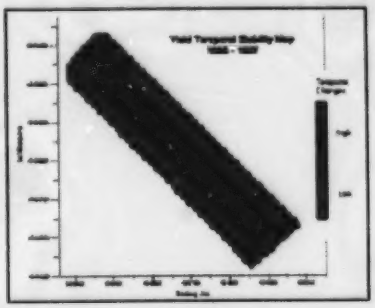

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Figure 9 - Yield Temporal Stability Map 1995-1997

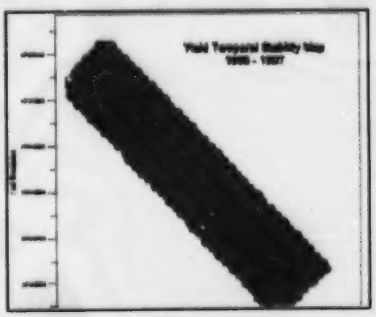

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Figure 9 is a map of the temporal stability that shows where the coefficient of variation is >30%, 30-20% 20-10% and 10-0%.

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Step 5:

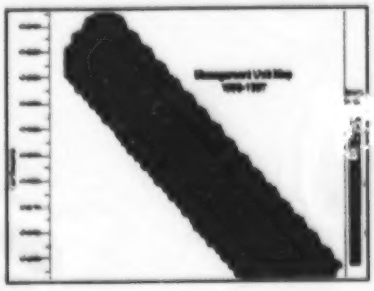
OUTPUT: MANAGEMENT UNIT MAP This map (Figure 9) is a display of those areas of the field where the yields are high and stable (green), low but stable (blue) and unstable (red) over time. The trick here is to combine the yield spatial trend map and the yield temporal stability map by applying a set of classification rules. This is done in the spreadsheet that was created in Step 4 by setting up an IF statement. The rules are:

	Average Normalized	Yield Coefficient of Variation
high yields and stable	> 100%	< 30%
low yields and stable	< 100 %	< 30%
unstable	<> 100%	> 30%

This new yield map or management unit map now shows the long term spatial variability of yields within this particular field. However, for this map to be of use the causes for this spatial pattern need to be explained. Low yielding areas of a field look much the same on a yield map regardless of the causes (compaction, low pH or drought stress). Unless a cause can be attributed no management response can be determined. Yield mapping must be complemented with field investigation.

The unstable areas along the right edge of the field are affected by a number of factors, such as the shading effect of the fence row, depressional areas that may pond and reduce yields and small knolls that may be prone to drought in some years. The large red zone occurred because the poor wheat yield caused the CV to become very large. The corn and soybean yields in this area are actually above average. In future years this red zone may disappear. One may also suspect that wheat yields will continue to yield poorly next time around. Some investigation is required to determine why the wheat yield was so low. (winter kill, manganese, soil type, drainage, disease, weeds etc...).

Figure 10 - Management Unit Map 1995-1997



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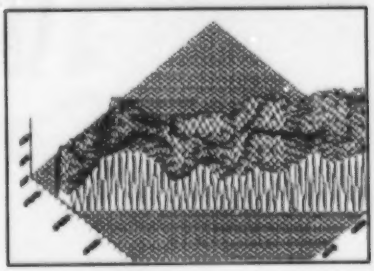
According to my calculations the high and stable areas cover 47.7% of the field, 34.1% is occupied by the low and stable yielding area and the remainder, unstable, takes up 18.1% of the field.

This new yield map or management unit map now shows the long term spatial variability of yields within this particular field. However, for this map to be of use the causes for this spatial pattern need to be explained. Low yielding areas of a field look much the same on a yield map regardless of the causes (compaction, low pH or drought stress). Unless a cause can be attributed no management response can be determined. Yield mapping must be complemented with field investigation.

The next question to consider is, do the three map units correlate with any soil, fertility or topographical characteristics of the field that would might provide us with some insight for the distribution of the management units within the field. To answer this let's examine the series of maps that follow.

The information required to generate these maps includes an elevation survey and soil sampling to a depth of 15 cm at 30 meter intervals (a total of 143 samples were collected). See Figure 11. Each sample was analyzed for pH, phosphorus, potassium, organic matter and texture. From the elevation data were derived % slope, aspect, elevation and landscape element maps.

Figure 11 - Location of Sample Points



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What follows is a series of paired maps. For each pair the first map shows the distribution of a particular soil, topographical or fertility property of the field. The second map is an overlay of the management unit on the property displayed. The areas that are cross hatched are for the low and stable and the unstable management units. The portion of the map without cross hatching represents the high and stable yielding management unit.

**** Please click HERE to go to the next page which contains the paired maps. ****

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General Conclusions

This method for creating management units using a set of yield maps can be accomplished quite easily using SURFER and EXCEL.

1. For this field there appears to be a fairly stable yield pattern for the 3 years of data used in this analysis. The management units are correlated with some soil and landscape properties which may have implications for management decisions.
2. The low and stable management unit (LSMU) is associated with the fine sand and loamy fine sands on the area of the field with a lot of shoulder and upper level topographical units. There is also a slightly higher percentage of slopes within this unit as well. All of these factors combined suggest that water availability may be the limiting factor to crop growth. The high and stable management unit (HSMU) are correlated with the very fine sandy loam and loam surface soils and with back slope, foot slope and lower level slope positions. These are areas of the field where water would tend accumulate. A lot of the unstable management unit (UMU) is located along the fence row where shading may in combination with ponding or doughtiness act to limit yields. The large red spot in the on the west side of the field is due to the extremely low wheat yield. The wheat in this area was thin and lying flat on the ground. The corn and soybeans yielded very well in this area. Topography and soil type together are influencing yield potential in this field.
3. Correlation between the management units and phosphorus, potassium, pH and organic matter was very poor.
4. This methodology also illustrates that if sufficient information is available in a format that allows for mapping that quick and simple overlaying of information provides valuable information to the producer.

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References

Larscheid, G., Blackmore, B. S. (1996) Interactions Between Farm Managers and Information Systems with Respect to Yield Mapping. Presented at 3rd International Conference on Precision Agriculture. June 23.26 1996 Minneapolis USA. P. C. Robert, R.H. Rust and W.E. Larson (Eds), Sponsored by ASA, CSSA, SSSA, ASAE, ASPRS & Univ. of Minnesota.

Larscheid, G., B. S. Blackmore, and M. Moore (1997) Management Decisions Based on Yield Maps. Presented at the First European Conference on Precision Agriculture. September 7.10 Warwick University Conference Centre, Warwick, UK. J. V. Stafford (Ed.) Volume II, Precision Agriculture '97.

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Update 2000

Yield Stability Index Maps

In this Precision Farming - Ontario update I have included a series of yield stability index (YSI) maps that have been derived from up to six years of yield monitor data. A portfolio of maps will be provided for each field that was included in the Ontario Site Specific Cropping Management Project. For each field there is a two-dimensional YSI map (Map 1); a smoothed version of Map 1, smoothing was accomplished with a generalized grid extension in Arcview 3.2 (Map 2); a three dimensional map of the smoothed YSI map draped over topography where applicable (Map 3) and a graph of yields versus YSI units for each year of yield data. There are up to nine YSI units per map. For an explanation of the mapping units please refer to Table 1. As an example, let's suppose that we have an area in a field where there are 3 years of above average yields and 3 years of below average yields. In this case we would expect to find an unstable average yield. In another area there may be 6 years of above average yields. This would translate to a YSI unit with very high and very stable yields.

YSI units can be combined or grouped to reduce the number of mapping units. The YSI units can be used as management zones for the purposes of sampling and the testing of the response to reducing or increasing inputs.

Table 1: Yield Stability Index Units

YSI Unit	Yield	Stability
1	Very low	Very stable
2		
3		
4		
5	Average	Unstable
6		
7		
8		
9	Very high	Very stable

A description of the methodology for creating these maps will be available in the near future.

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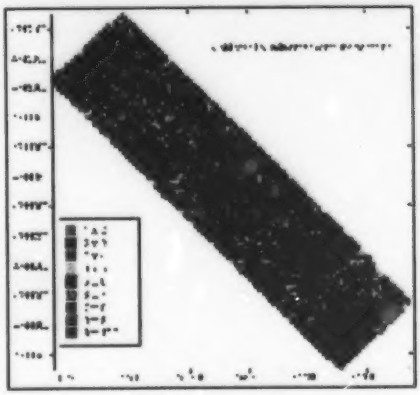
McCracken Field

Location:	Caradoc Township, Middlesex County
Size:	30 acres
Topsoil:	loamy fine sand, loamy very fine sandy loam, very fine sandy loam, loam, parent materials range from glaciolacustrine fine sands to sand over clay loam till
Elevation:	ranges from 223.9 to 229.8 m
Cropping History:	1995 corn, 1996 soybeans, 1997 winter wheat, 1998 corn, 1999 corn, winter wheat

Map 1: The Spatial Distribution of the Yield Stability Index for the McCracken Field



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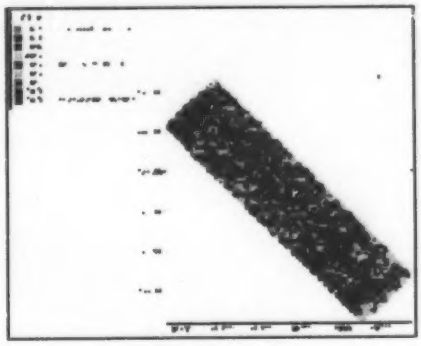
Map 2: The Spatial Distribution of the Smoothed Yield Stability Index for the McCracken Field



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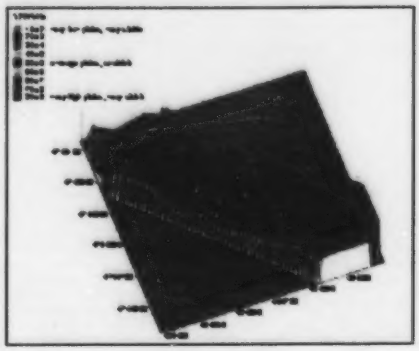
Map 3: Topography and the Spatial Distribution of Yield Stability Index Units



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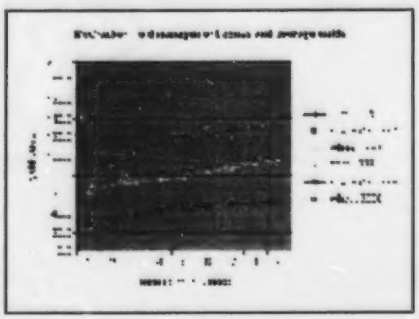
McCracken Field Management Zones and Average Yields



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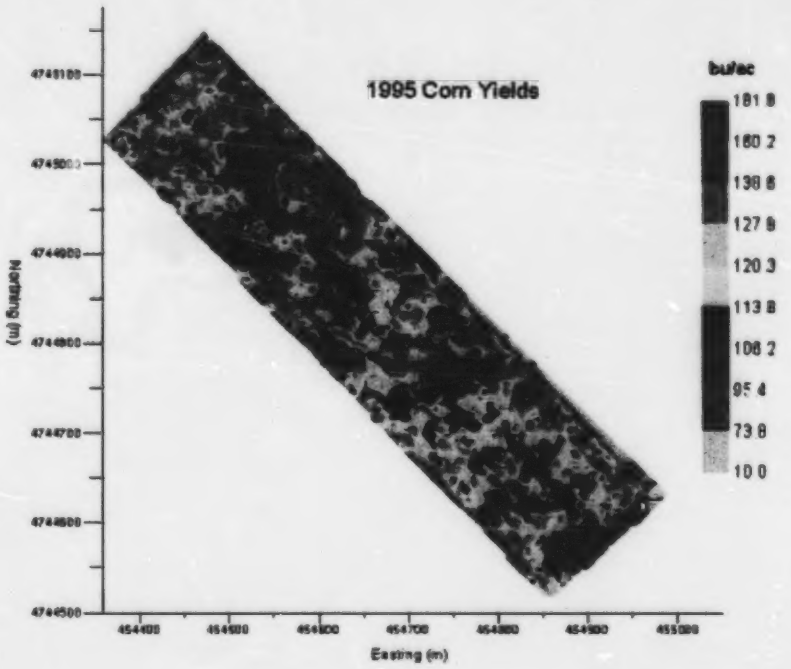
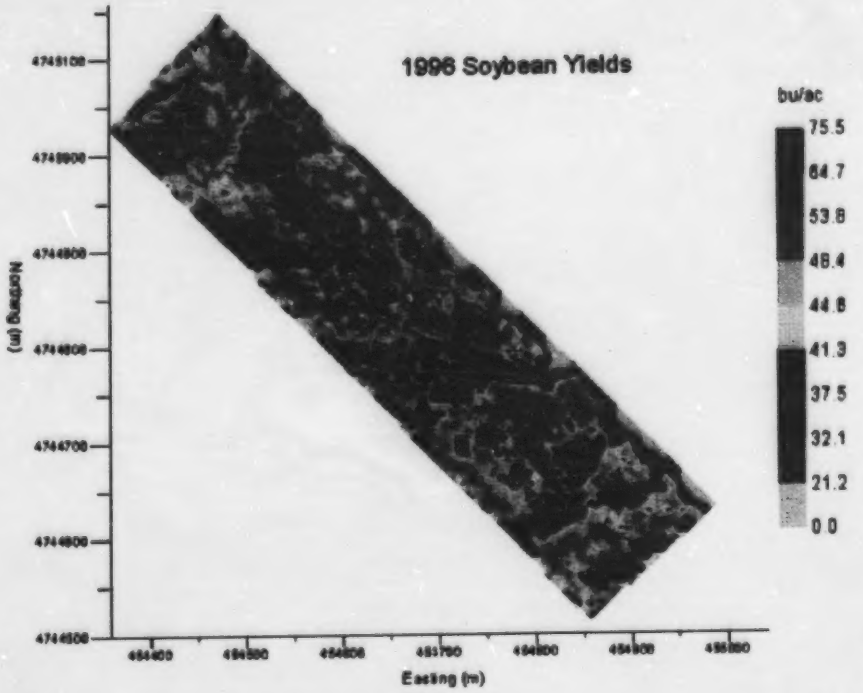
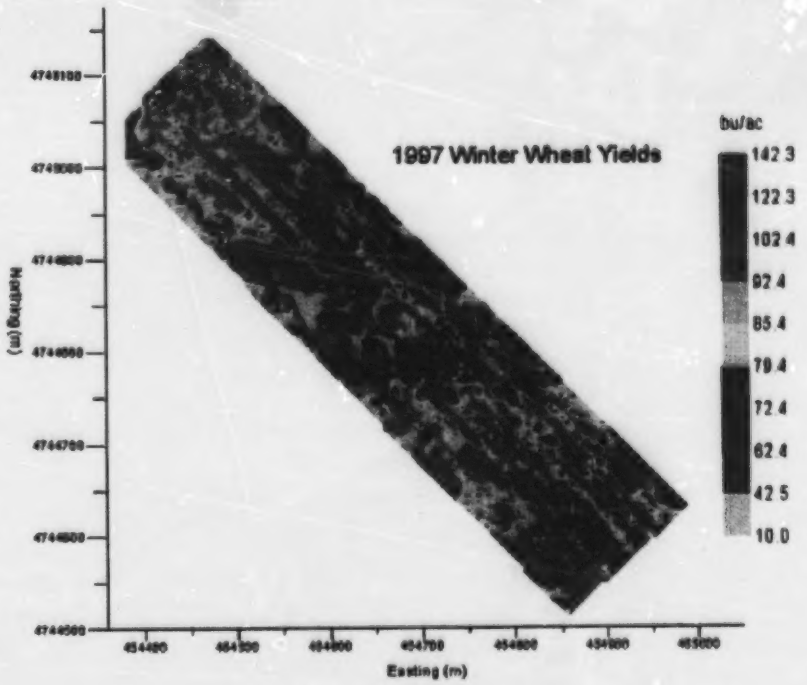

1995 Corn Yields
bu/ac
181 8
160 2
138 6
127 8
120 3
113 8
106 2
95 4
73 8
10 0
Northing (m)
4745100
4745000
4744900
4744800
4744700
4744600
4744500
454400
454500
454600
454700
454800
454900
455000
Easting (m)


1996 Soybean Yields
bu/ac
75.5
64.7
53.8
48.4
44.8
41.3
37.5
32.1
21.2
0.0
Northing (m)
4745100
4745000
4744900
4744800
4744700
4744600
4744500
Easting (m)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bu/ac
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92.4
85.4
79.4
72.4
62.4
42.5
10.0
Northing (m)
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4748000
4747900
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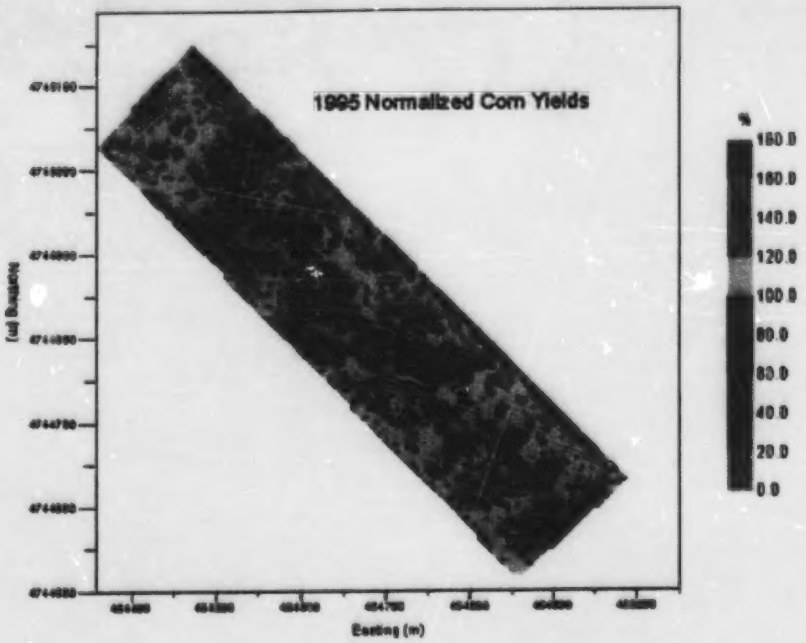
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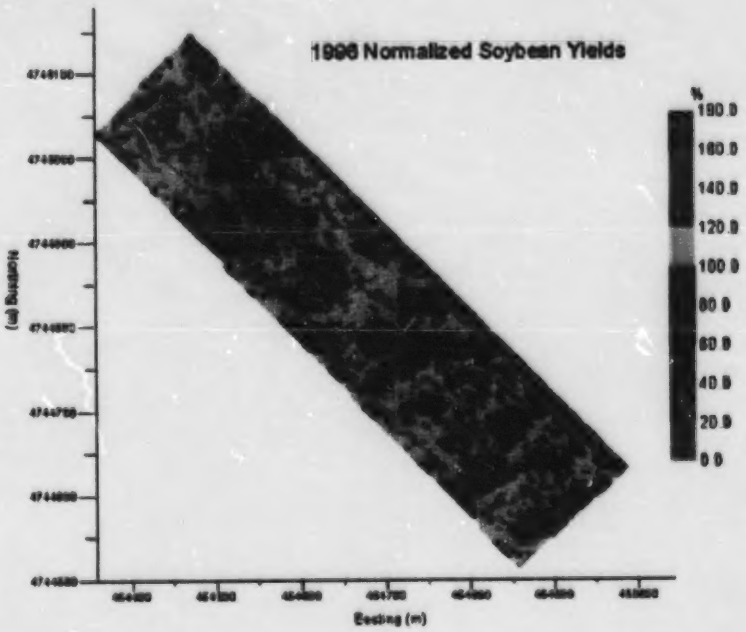
80.0
60.0
40.0
20.0
0.0
Easting (m)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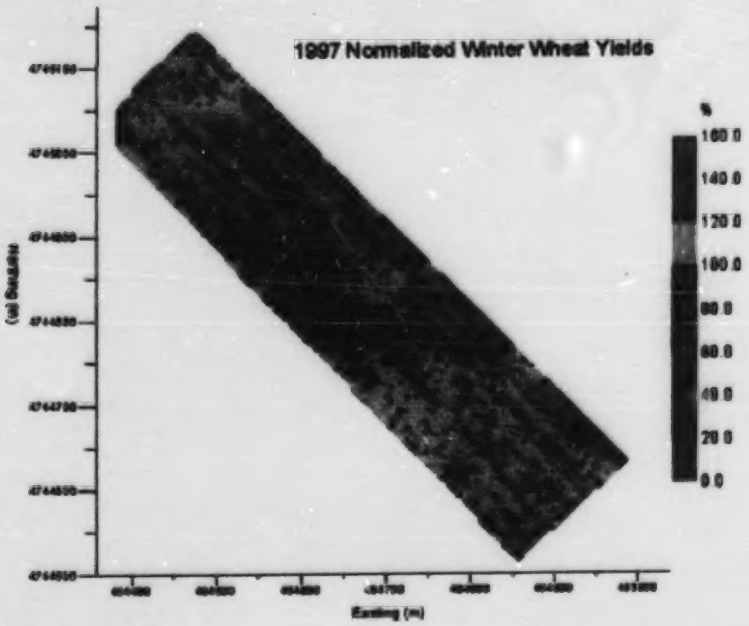
40.0
20.0
0.0
Easting (m)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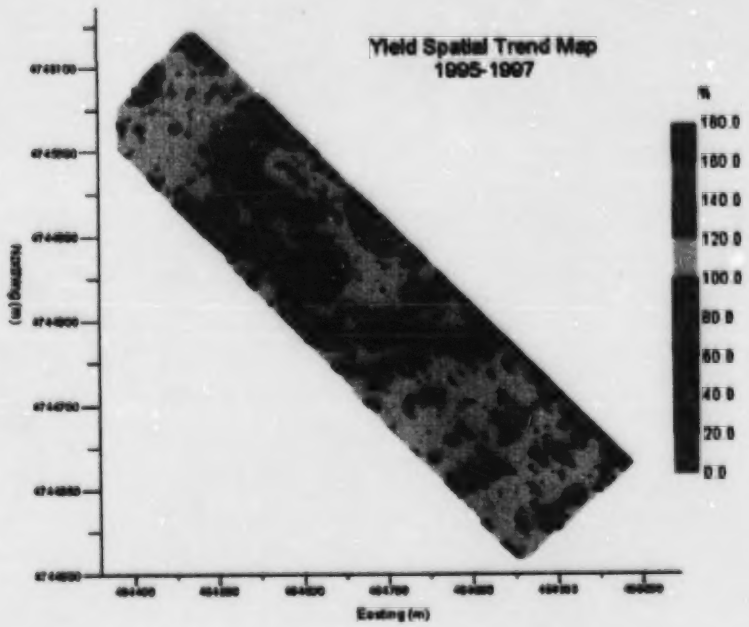
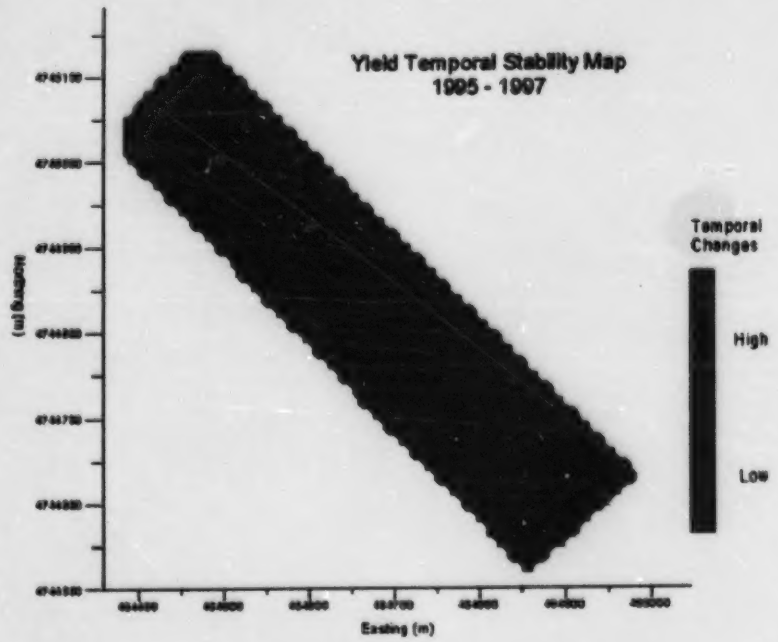
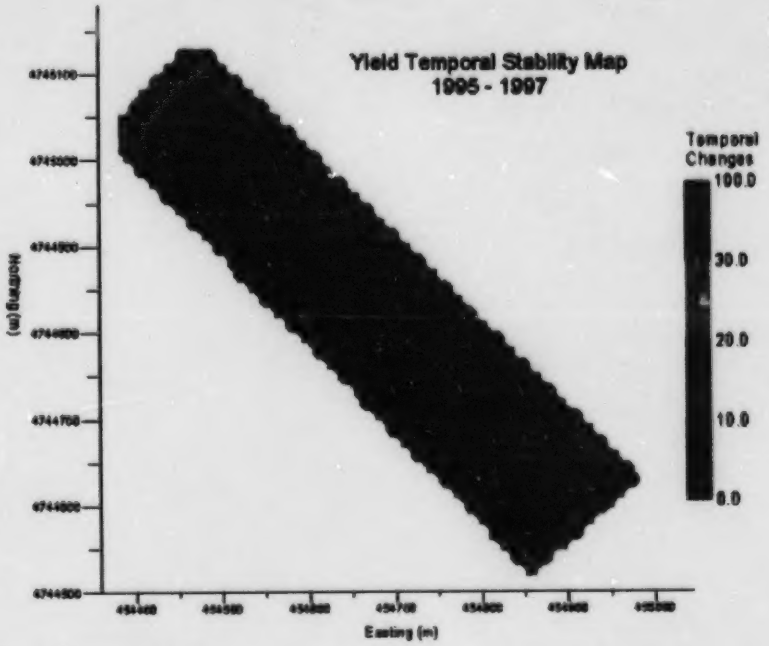
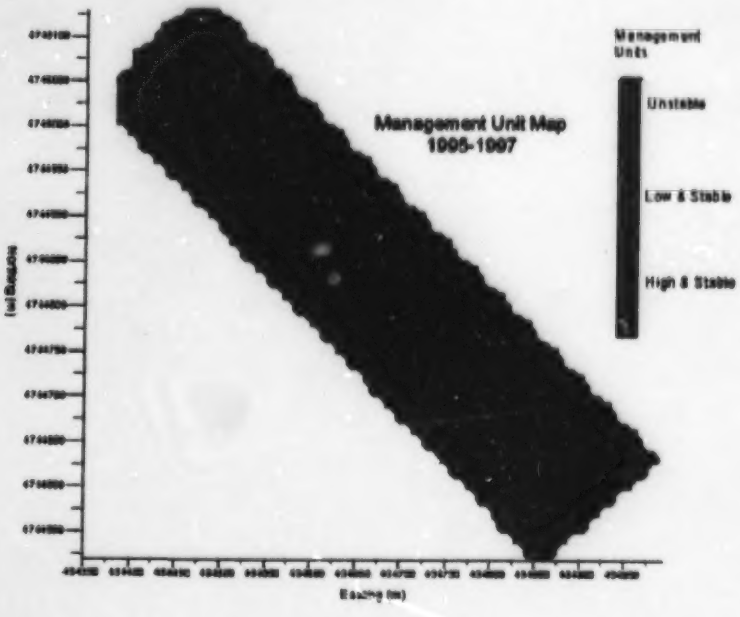
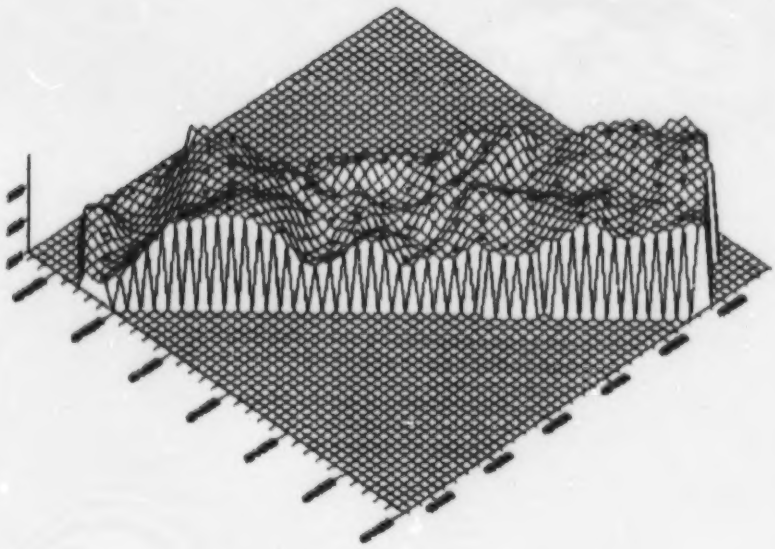
80.0
60.0
40.0
20.0
0.0

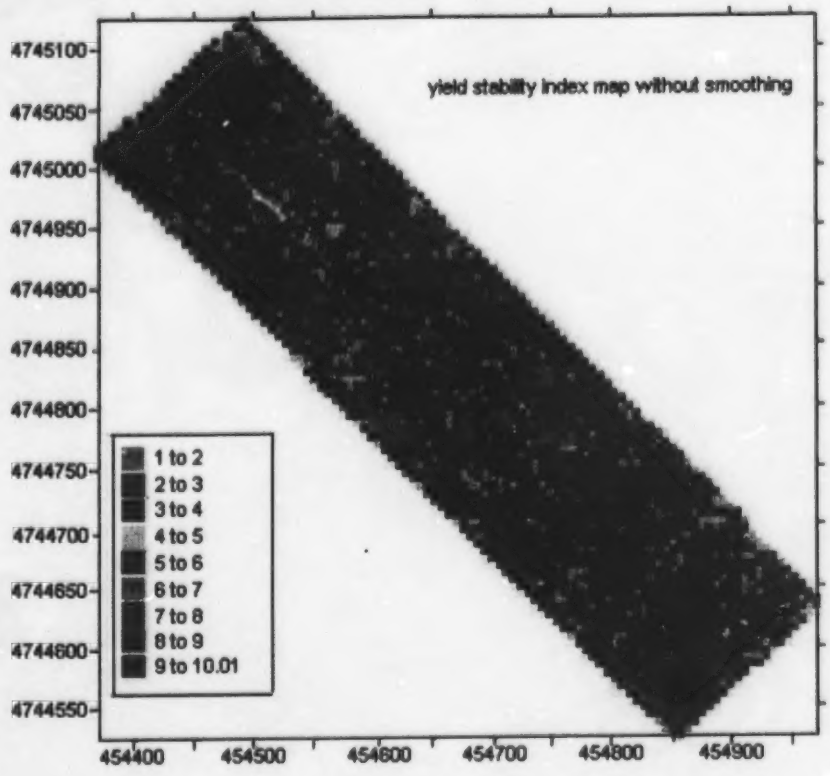

Yield Spatial Trend Map
1995-1997
%
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Easting (m)

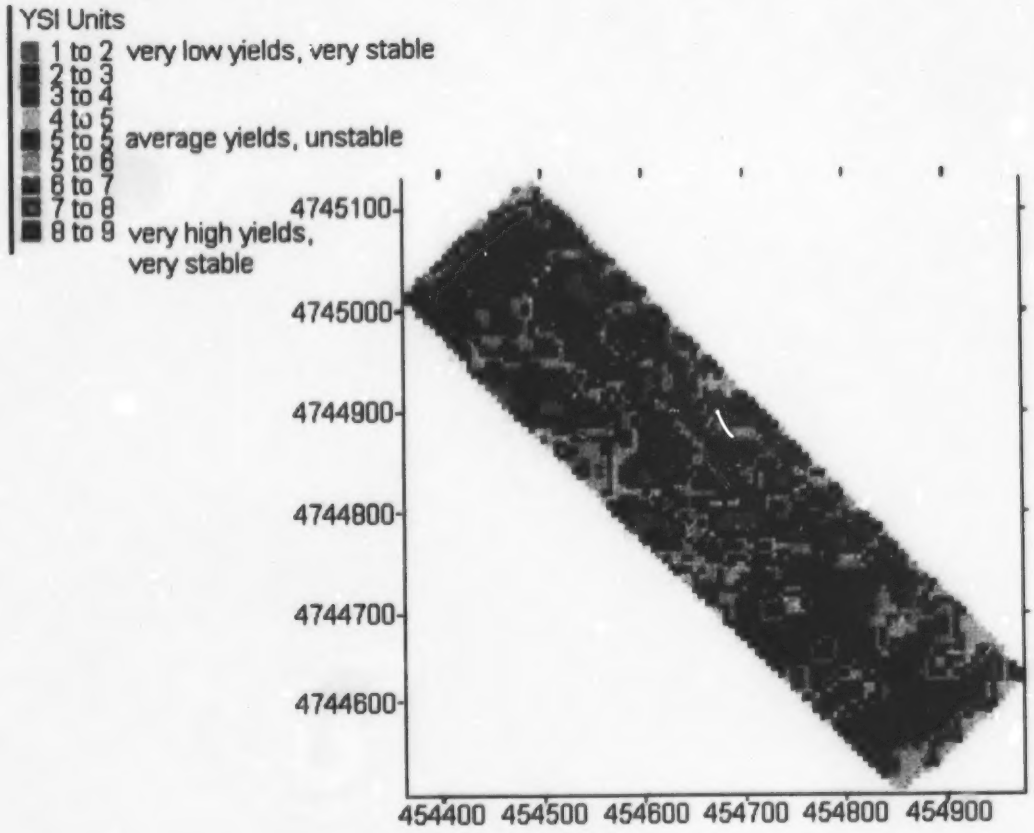

Yield Temporal Stability Map
1995 - 1997
Temporal Changes
High
Low
Northing (m)
Easting (m)

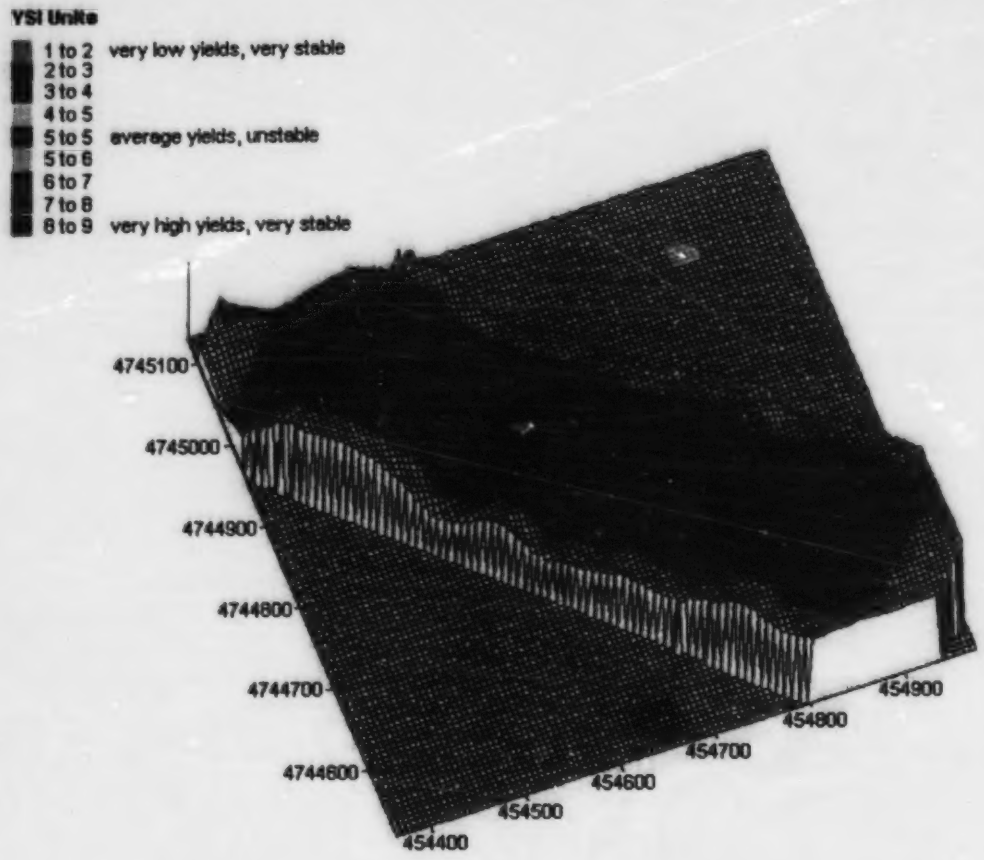

Yield Temporal Stability Map
1995 - 1997
Temporal Changes
100.0
30.0
20.0
10.0
0.0
Northing (m)
Easting (m)

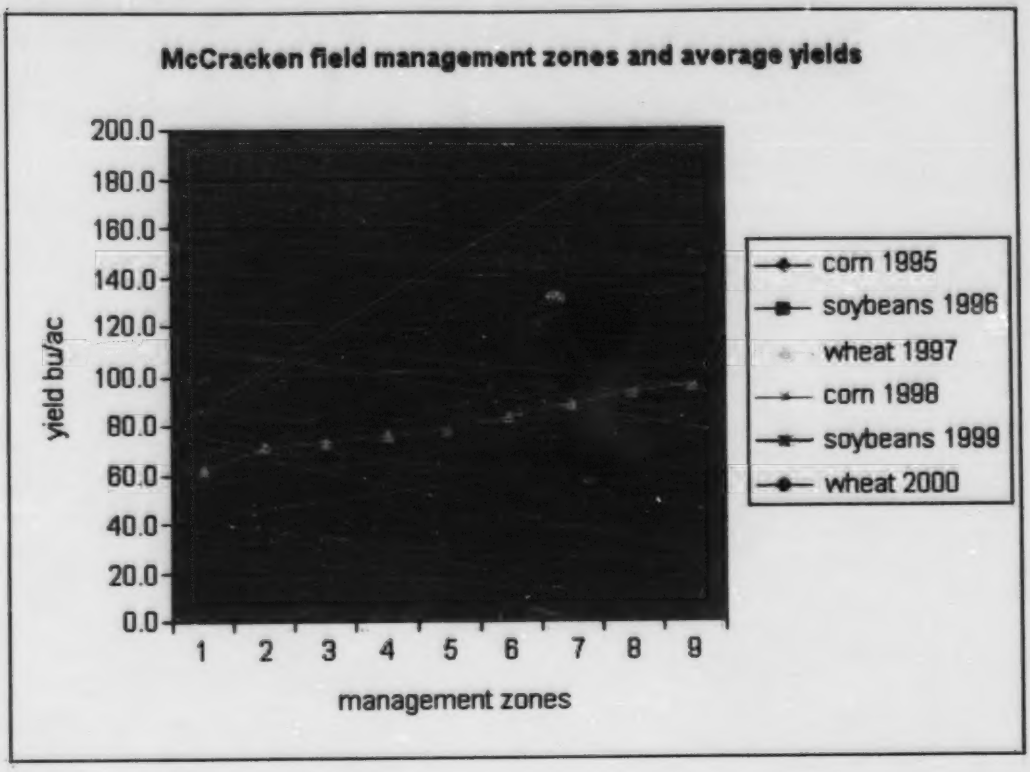

Management Unit Map
1995-1997
Management Units
Unstable
Low & Stable
High & Stable




yield stability index map without smoothing
4745100
4745050
4745000
4744950
4744900
4744850
4744800
4744750
4744700
4744650
4744600
4744550
454400
454500
454600
454700
454800
454900
1 to 2
2 to 3
3 to 4
4 to 5
5 to 6
6 to 7
7 to 8
8 to 9
9 to 10.01


YSI Units
1 to 2 very low yields, very stable
2 to 3
3 to 4
4 to 5
5 to 5 average yields, unstable
5 to 6
6 to 7
7 to 8
8 to 9 very high yields, very stable
4745100
4745000
4744900
4744800
4744700
4744600
454400 454500 454600 454700 454800 454900


YSI Units
1 to 2 very low yields, very stable
2 to 3
3 to 4
4 to 5
5 to 5 average yields, unstable
5 to 6
6 to 7
7 to 8
8 to 9 very high yields, very stable
4745100
4745000
4744900
4744800
4744700
4744600
454400
454500
454600
454700
454800
454900


McCracken field management zones and average yields
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
yield bu/ac
1
2
3
4
5
6
7
8
9
management zones
corn 1995
soybeans 1996
wheat 1997
corn 1998
soybeans 1999
wheat 2000